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INTERPRETATION OF GEOCHEMICAL, RADIOMETRIC AND ISOTOPIC DATA ON KULA VOLCANICS (MANİSA-W.ANATOLIA)

Kula volkanitlerinin jeokimyasal, radyometrik ve izotopik verilerinin yorumu (Manisa - Batı Anadc lu)

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ABSTRACT: Alkaline basaltic rocks of Quaternary age are dominant in the vicinity of Kula town in the Manisa province in Western Anatolia (Turkey). Tliese volcanics are represented by three distinct stages of volcanic activity. The first stage forms I, I m. y. old flood basalts. The last stage occured about 20.000 years ago and are of cinder and spatter cones, "aa" type lava flows, tuffs and tephras. "Base Surge" type bed forms have been observed around some maar volcanoes of second stage and pirimitive human footprints are observed in third stage tuffs. Kula alkali volcanics are located within the Western Turkey Graben System which was formed as a result of the Aegean extensional tectonic regime. Abundant mantle xenoliths were brought up by the eruptions of the second and third volcanic activity periods. These xenoliths consist of olivine + kaersutite + apatite + cpx ± phlogopite ± sphene indicating modal metasomatism of the Subcontinental lithosphere. Strontium isotopic ranges for Kula basalts are 87 Sr/86 Sr= 0,7020 - 0,7035. According to petrochemical investigations there is no chemical difference between the lavas of all three stages and all the lavas are more alkaline. They derived from an alkali olivine basaltic magma and have a mantle origin. The lavas are partly sodic and partly polassic. Their potassium content increase from first to third stage. The younger lavas are more potassic then the old ones. Noble gas and helium isotopic composition in gas samples from the Kula volcanic province were measured and nearly mantle-derived helium was found in all the samples. The highest 3He/4He ratio was 3,92x10*6. Volatile gasss including helium released from mantle or diapiric magma interact chemically with marine carbonate in the crust and evolved carbon dioxide and radiogenic helium dilute the original magmatic gas. Therefore, it is possible that Kula volcanism will be re-active and new alkali basaltic lavas will be formed in the future.

ÖZ: Türkiye'de Batı Anadolu'nun Manisa ilinin Kula ilçesi civarında Kuvaterner yaşlı alkali bazaltik kayaçlar yaygındır. Bu volkanikler 3 belirgin safhada temsil olunurlar. İlk evreye ilişkin bazalt akıntıları I, I milyon yıl yaşlıdır. Son evre 20.000 yıl önce etkin olmuş olup sinder ve spatter türde volkan konileri, aa tip lav akıntıları, tüf ve tefralardan oluşur. İkinci evreye ilişkin bazı maar türde volkanların çevresinde "Base Surge" türde yataklanmalar ve üçüncü evrenin tüllerinde ilkel insanlara ait ayak izleri gözlenir. Kula alkali volkanikleri, Ege Bölgesi gerilme tektonik rejiminin sonucu olarak meydana gelen Batı Anadolu graben sistemlerinde yer alır. İkinci ve üçüncü evre erüpsiyonlarıyla bol miktarda manto ksenolitleri getirilmiştir. Bu ksenolitler, olivin + kersütit + apatit + klinopiroksen ± flogopit ± sfen parajenezinde olup, subkontinental Litosferin modal metasomatizmasına işaret ederler. Kula bazaltlarının Stronsiyum izotopik oranları 87 Sr/86 Sr= 0,7020-0.7035'tir. Petrokimyasal incelemelere göre, her üç evrenin bazaltları arasında kimyasal bir farklılık olmayıp, hepsi aşırı alkali karakterdedir. Lavlar, alkali olivin bazaltik bir magmadan türemiş olup manto kökenlidir. Lavlar kısmen sodik, kısmen de potassiktir. Potasyum içeriği, birinci evreden üçüncü evreye doğru artar. Genç lavlar, yaşlılara nazaran daha potassiktir. Alınan gaz örneklerindeki asal gaz ve Helyum izotopik bileşimleri Kula bölgesi için ölçülmüş olup, tüm örneklerde hemen hemen manto kökenli helyum saptanmıştır. En yüksek 3He/4He oranı 3,92 x 10^{-6} dır. Manto veya diyapirik magmadan serbestlenen Helyum kapsayan volatil gazlar, denizel karbonatlarla kimyasal reaksiyona girerek karbondioksit ve radyojenik Helyum üretmişler ve orjinal magmatik gazları seyreltmişlerdir. Buna göre, Kula volkanizmasının yeniden faaliyete geçebileceği ve ilerde yeni alkali bazaltlar üretebileceği öne sürülebilir.

INTRODUCTION

The Kula volcanics crop out in an area of 30-35 Km. length and 10-15 Km. width in Manisa province, Turkey. These are Quaternary alkali basaltic lava flows and tephras. Kula is one of the areas which the young volcanic rocks arc seen in Turkey. Investigators worked in Kula even in ancient times. For example, famous historian Strabon travelled to Kula and named it as "Katakekaumane" (burnt-land) 2000 years ago. After him, many scientists have visited this region.

GEOLOGICAL OUTLINE

The volcanic area extends from Kula town to the west of the Demirköprii Dam (Fig. 1A and IB) and is mostly on a plateau, 600-700 m. high. This plateau is bordered by Gediz River in the north and the Alaşehir-Salihli graben in the south. Volcanic cones are seen in NW-SE direction, fitting the extension of the Alaşehir-Salihli graben (Fig. 2) and related to the graben systems of Western Anatolia. "Aa" type lavas were formed by a typical "fissure" volcanism. There are "hornitosses" on the lavas and scorias. The lava tunnels are observed in places. All the volcanoes are in "Maar" type. Volcanic cones are in "sinder" or "spatter" type. They show some differences according to their ages and erosional grades. Craters of the old cones are bigger than the younger ones. The cones consist of lavas, lapillics, scorias and the pyroclastics such as volcanic bombs in various coarseness. Black basaltic lava flows are seen around these cones. The youngest cones have views the same as actual ones. Some cones have double craters.

Kula volcanism has been active in three different stages in the investigated area, namely the "Burgaz volcanics", "Elekçitepe volcanics" and "Divlittepe volcanics" (Ercan, 1981).

Burgaz volcanics

They are the protucts of the first stage and overlie to the older rock units as plateau basalts on the hills. These are on higher altitude than the volcanics of the second and the third stages. The volcanic cones have been spoiled and their shapes have been rounded in time. Lavas form high plateaus wich have slopes up to 30-40 m. high. Tertiary aged sediments have been abundantly erroded between the first and the second explosion stages. Thus the lavas of the second stage have been occured on the lower levels. The K/Ar method of the radiometric dating on Burgaz volcanics have been carried out by Borsi et al. (1972) who have reported an age of 1,1 ma. Tertiary sediments which are underlain by Burgaz volcanics have been cooked by the heat of the lavas and 2-3 m. thick contact zone has occured. Hexagonal cooling faces are seen in basalts.

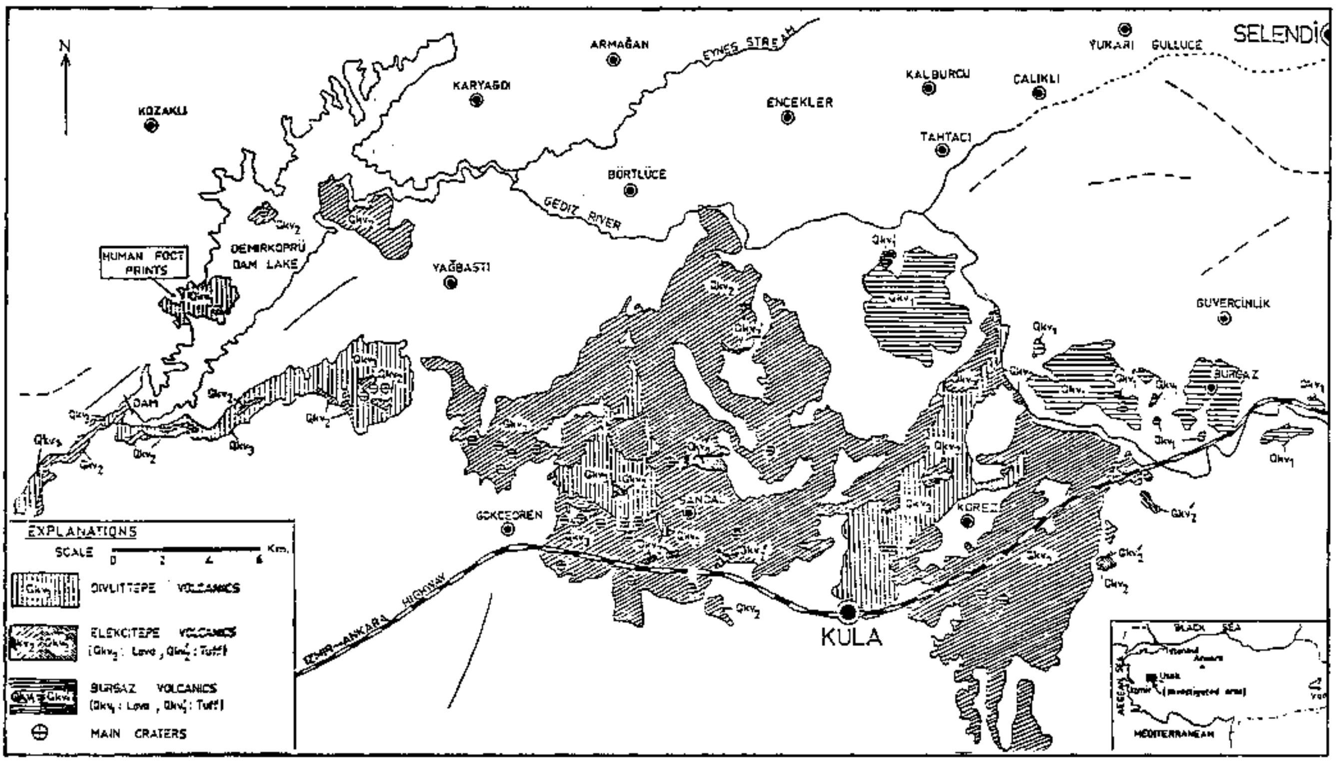


Figure I/A. Distribution of Quaternary Kula basalts in the study area
Şekil l/A. Çalışma alanında Kuvatcrncr yaşlı Kula bazaltlannm dağılır

Elekçitepe voîcanics

The volcanic cones and craters of the second stage of Kula volcanics have been erroded less than that of the first stage and have maintained their shapes to a higher extend than the older ones.

Base surge deposits wich is a result of turbulent mixtures of steam and solid ejecta are only seen in this second stage volcanism (Ercan and Öztunalı, 1982).

More than 45 volcanic cones were observed. Some of them have been erroded. Frequent lava eruptions occured. Some chimneys were closed and most of the cones have subsided and broken. Erinç (1970) who made geomorphologic investigations in the area surround ig Kula suggested that the second stage of the volcanism was more intensive then the first stage and the volcanic producst of this stage are 2,6 km3 in volume. Deleuil (1977) found a 0,3±0,1 million year age of Elekçitepe volcanism by K/Ar method.

SAMPLE NO	KU 51 KULA İNCİRLİK	KU 52 KULA İNCİRLİK	KU 53 KULA BOZTEPE	KU 54 KULA BURGAZ KÖYÜ	KU 55 KULA İNKALE T.	KU 56 KULA KAYTEPE	KU 57 KULA SARNIÇ KÖYÜ	KU 58 KULA KARGILIK	KU 59 KULA ÇAKIRCA	KU 61 KULA KIRAN SR	KU 62 KULA İBRAHİM AĞA KÖYÜ	KU 29 KULA GEDİZ VADİSİ	KU 33 KULA KIRPINI T.	KU 35 KULA PALAN-KAYA MAH	KU 37 KULA PALAN-KAYA MAH	KU 43 KULA DİVLİT T.	KU 50 KULA KEPEZ	KU 96 KULA SANDAL KÖYÜ	KU 97 KULA ERİKLİ T.
SiO_2	47.65	47.45	46.65	48.60	47.40	50.15	49.55	48.35	47.40	49.00	50.75	45.88	46.40	46.25	45.65	46.55	46.45	43.20	44.05
Al_2O_3	16.51	14.71	14.83	16.85	14.99	17.99	15.09	16.58	14.75	17.73	16.19	16.53	17.26	16.66	18.40	17.91	15.72	18.25	18.52
Fe_2O_3	3.07	3.04	3.79	4.04	2.39	[illegible]	2.64	3.85	2.42	3.49	2.78	2.87	6.47	4.46	5.18	4.08	3.40	5.17	6.39
FeO	5.17	5.73	4.82	5.29	6.49	[illegible]	5.63	4.55	5.94	4.60	5.21	5.47	3.70	6.47	5.73	4.99	5.56	4.80	2.96
MgO	5.70	8.00	8.00	3.70	5.30	1.90	5.60	5.50	6.90	4.20	5.50	6.90	7.30	5.20	4.40	7.20	6.20	6.83	7.06
CaO	9.30	10.07	10.20	8.68	10.11	8.00	10.54	10.27	11.15	7.56	7.29	9.73	9.33	9.28	8.95	8.17	9.18	10.11	9.51
Na_2O	4.80	4.20	4.20	5.22	3.55	5.45	4.20	4.00	3.20	6.00	5.35	5.97	3.95	4.00	5.25	4.20	4.85	4.18	5.10
K_2O	1.60	1.15	1.20	1.65	2.30	1.40	1.10	0.85	1.65	1.35	3.30	1.68	2.30	2.10	1.35	2.63	1.20	2.63	2.70
H_2O	1.83	1.46	2.16	1.96	2.02	3.31	1.29	1.81	2.61	2.26	—	1.47	0.26	0.30	0.85	0.47	2.49	0.46	0.45
TiO_2	2.04	2.04	2.06	2.26	2.02	2.02	2.10	2.09	2.03	1.87	1.72	2.17	2.02	2.11	2.17	1.98	1.94	2.34	2.41
P_2O_5	0.78	0.73	0.64	0.87	0.69	0.92	0.83	0.85	0.73	0.64	0.81	1.13	1.04	1.34	1.64	0.99	1.35	0.68	0.76
MnO	0.16	0.15	0.15	0.16	0.15	0.15	0.14	0.15	0.16	0.18	0.17	0.16	0.16	0.19	0.18	0.16	0.18	0.99	0.41
CO_2	0.56	0.42	0.50	0.35	0.42	0.35	0.38	0.58	0.62	0.42	0.50	—	0.61	0.44	0.67	0.39	0.27	—	—
TOPLAM (Total)	98.99	99.93	99.00	99.63	98.23	100.55	100.03	99.43	99.36	99.50	99.57	99.96	100.80	98.80	100.42	99.72	98.59	99.77	100.02
Q	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Or	9.55	6.80	7.16	9.78	13.83	8.22	6.60	5.05	9.81	8.02	19.58	9.93	13.48	12.56	7.96	15.58	7.19	15.57	15.85
Ab	28.55	27.32	25.30	33.81	23.78	44.28	32.02	34.04	23.33	37.35	27.32	15.30	22.76	26.40	31.19	21.21	29.07	4.35	6.04
An	18.97	17.90	18.25	17.74	18.50	20.37	19.05	24.91	21.16	12.54	10.46	13.35	22.39	21.56	22.56	22.31	17.83	23.32	19.66
Hy Fs	—	—	—	—	—	—	—	0.48	—	—	—	—	—	—	—	—	—	—	—
Hy En	—	—	—	—	—	—	—	3.27	—	—	—	—	—	—	—	—	—	—	—
Mt	4.49	4.41	5.55	5.81	3.53	5.59	3.82	5.61	3.53	5.08	4.05	4.16	6.54	6.54	7.48	5.90	5.00	7.51	4.76
Hm	—	—	—	—	—	1.61	—	—	—	—	—	—	1.90	—	—	—	—	—	3.10
Cc	1.33	0.95	1.15	0.80	0.97	0.79	0.86	1.32	0.96	0.96	1.14	—	1.37	1.01	1.51	0.89	0.62	—	—
Ap	1.86	1.73	1.53	2.07	1.66	2.16	1.96	2.02	1.74	2.00	1.92	2.67	2.44	3.21	3.87	2.35	2.76	1.61	1.80
Ne	6.76	4.46	5.76	5.70	3.66	0.86	1.89	—	2.12	7.40	9.83	19.04	5.62	4.26	7.06	7.81	6.60	15.84	20.10
Ol Fo	6.11	8.72	8.17	3.91	4.84	0.57	6.29	3.48	6.68	4.85	6.16	6.21	9.36	6.58	6.23	10.40	7.04	6.88	6.62
Ol Fa	1.86	2.37	1.00	1.02	2.78	—	2.08	0.56	2.51	1.43	2.35	1.74	—	2.83	1.87	1.81	2.28	1.23	—
Di Wo	7.86	10.79	10.62	7.33	10.55	4.56	10.59	7.12	11.29	4.99	7.25	11.50	5.41	5.58	2.82	3.91	7.94	9.39	9.41
Di En	5.61	7.49	8.46	5.09	6.52	3.94	7.45	5.54	7.75	3.58	4.96	8.32	4.67	3.71	2.02	3.02	5.61	7.22	8.13
Di Fs	1.53	1.85	0.94	1.63	3.40	—	2.24	0.81	2.66	0.96	1.72	2.12	—	1.45	0.55	0.47	1.66	1.17	—
Il	3.91	3.87	3.95	4.31	3.90	3.81	3.98	3.99	3.88	3.57	3.28	4.12	3.60	4.05	4.10	3.77	3.73	4.45	4.00
Al	15.01	13.24	13.48	15.21	13.73	16.10	13.57	15.01	13.36	16.03	14.63	14.88	15.40	15.17	16.49	16.16	14.36	16.46	16.66
Alk	8.89	7.45	7.57	9.52	7.75	9.53	7.40	6.88	6.49	10.40	11.36	10.63	8.16	8.20	9.18	8.95	8.60	8.92	10.35
FM	20.53	24.94	25.29	17.49	20.66	13.14	22.15	20.13	23.07	17.23	19.77	22.86	25.11	22.44	20.40	24.20	22.43	25.40	24.21
k	0.14	0.15	0.16	0.17	0.30	0.14	0.15	0.12	0.25	0.13	0.29	0.16	0.28	0.26	0.14	0.29	0.14	0.29	0.26
an	0.25	0.28	0.28	0.23	0.28	0.25	0.29	0.37	0.34	0.31	0.12	0.16	0.30	0.30	0.28	0.24	0.25	0.29	0.23
P	45	46	46	45	48	47	49	52	49	45	42	39	46	47	44	46	45	43	41
RITTMANN'S NAME	Andesine Basalt	Andesine Basalt	Andesine Basalt	Nepheline Tephrite	Olivine Andesine Trachybasalt	Andesine Basalt	Andesine Basalt	Andesine Basalt	Olivine Andesine Trachybasalt	Nepheline Tephrite	Phonolitic Nephline Tephrite	Phonolitic Nephline Tephrite	Olivine Andesine Trachybasalt	Olivine Andesine Trachy basalt	Nepheline Tephrite	Nepheline Basanit	Andesine Basalt	Nepheline Basanite	Nepheline Basanite
IRVINE & BARAGAR'S NAME	Hawaiite (Sodic)	Hawaiite (Sodic)	Hawaiite (Sodic)	Hawaiite (Sodic)	Alkaline Basalt (Potassic)	Hawaiite (Sodic)	Hawaiite (Sodic)	Hawaiite (Sodic)	Alkaline Basalt (Potassic)	Mugearite (Sodic)	Trachybasalt (Potassic)	Hawaiite (Sodic)	Alkaline Basalt (Potassic)	Trachybasalt (Potassic)	Hawaiite (Sodic)	Trachybasalt (Potassic)	Hawaiite (Sodic)	Alkaline Basalt (Potassic)	Trachybasalt (Potassic)
N.P.C.	32.27	33.99	34.36	28.05	38.21	30.83	35.14	42.26	44.04	26.09	19.31	22.08	41.06	39.16	34.42	39.45	30.62	41.83	33.21
N.C.I.	26.22	29.68	29.31	21.45	25.61	16.12	26.78	24.52	27.90	19.94	23.10	27.75	27.03	25.60	22.52	25.92	26.00	29.40	27.90
D.I.	46.85	38.59	38.21	49.30	41.30	53.37	40.40	39.09	35.27	52.78	56.73	46.36	[illegible]	43.22	46.21	46.61	43.07	36.78	42.09
S.I.	28.02	36.17	36.58	18.59	26.48	10.75	32.72	29.31	34.31	21.38	24.84	30.14	34.78	23.39	20.08	31.17	29.23	28.77	29.16
σ	8.14	5.87	7.22	8.23	6.26	6.75	4.31	4.23	5.06	8.74	9.47	20.21	12.68	10.00	17.57	12.75	9.15	155.52	58.41
τ	5.74	5.15	5.16	5.14	5.65	6.29	5.18	6.02	5.70	6.27	6.29	4.87	6.60	5.94	6.06	6.90	5.59	6.00	6.36
Log σ	0.91	0.77	0.86	0.91	0.79	0.83	0.63	0.62	0.70	0.94	0.97	1.30	1.10	1.00	1.24	1.10	0.96	2.19	1.76
Log τ	0.76	0.71	0.71	0.71	0.75	0.79	0.71	0.78	0.75	0.79	0.80	0.68	0.82	0.77	0.78	0.84	0.74	0.78	0.80
$(FeO+Fe_2O_3)/SiO_2$	0.17	0.18	0.18	0.19	0.16	0.17	0.16	0.17	0.17	0.16	0.15	0.18	0.22	0.23	0.24	0.19	0.19	0.23	0.21
Al_2O_3/SiO_2	0.34	0.30	0.31	0.34	0.31	0.36	0.30	0.34	0.31	0.36	0.32	0.36	0.37	0.36	0.40	0.38	0.34	0.42	0.42
$Na_2O+K_2O/Na_2O+K_2O+CaO$	0.40	0.34	0.34	0.44	0.38	0.46	0.33	0.32	0.30	0.49	0.54	0.44	0.40	0.39	0.42	0.45	0.42	0.40	0.45
An.100/(Ab+An)	39.92	39.58	41.90	34.41	43.75	31.50	37.30	42.25	47.53	31.95	27.68	46.46	49.58	44.85	41.97	51.26	38.01	84.27	76.49
K_2O/Na_2O	0.33	0.27	0.28	0.31	0.64	0.25	0.26	0.21	0.51	0.22	0.61	0.28	0.58	0.52	0.25	0.62	0.24	0.63	0.53
ROCK GROUPS	KULA (BURGAZ) VOLCANICS Qkv1											KULA (ELEKÇİTEPE) VOLCANICS Qkv2							
SYMBOLS	+											▲							

Table 1. The results of the major element chemical analysis, the C. I. P. W. norms and the Rittmann parameters of Kula volcanics

Tablo 1. Kula volkanitlerinin majör element kimyasal analizleri, C. I. P. W. normları ve Rittmann parametreleri

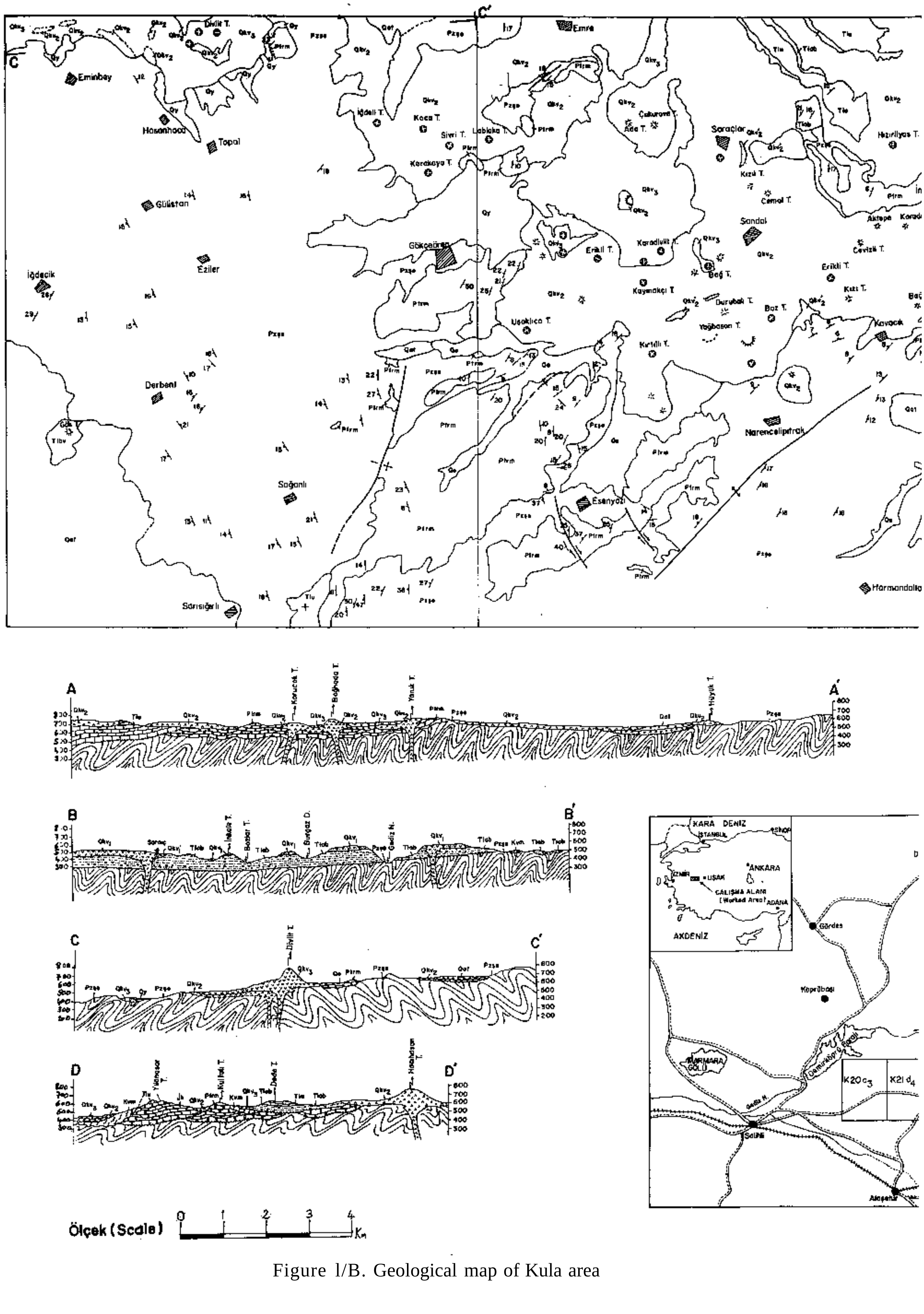
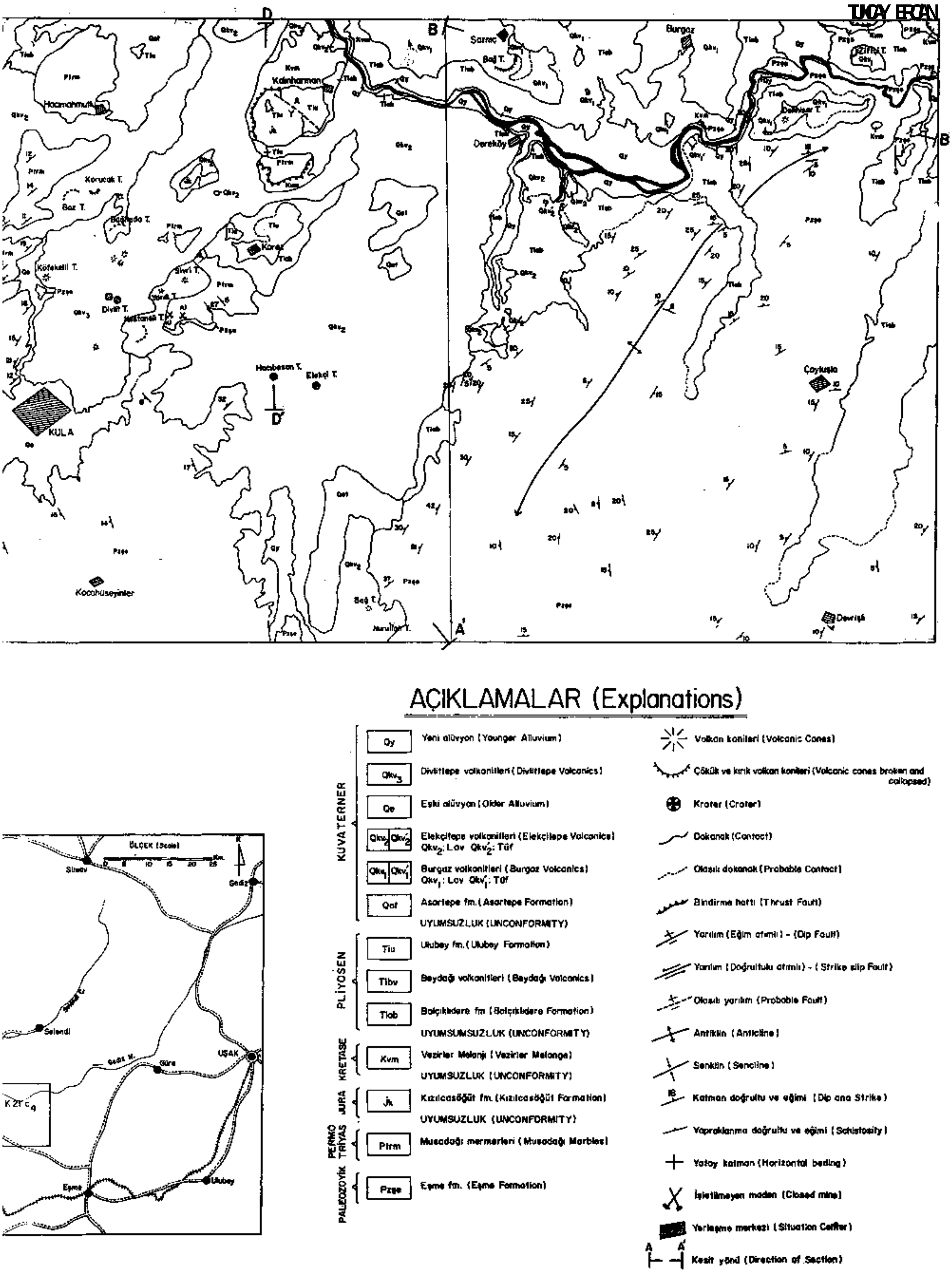


Figure l/B. Geological map of Kula area



Şekil 1/B. Kula yöresinin jeoloji haritası

Divlittepe volcanics

Volcanic cones, craters, and lava flows related to Divlittepe volcanics which have been formed in the third stage are completely seen as recent volcanism. They flowed in valleys and went on alluvial sediments for kilometers. The lavas are Fresh as if they have just occured. There is not any plant cover on them .It is difficult to walk on the lavas and scorias. Lavas and scorias cover a 60 km^ area. Lavas are distinguishable among the ones belonging to the other stages, and consist of very fluent basalts. They had gone long distances, and lava falls had been created. The gases which had been accumulated in lava Flows occasionally had formed hornitos on surface, and the lava tunnels were formed in some lavas. Primitive human being used the craters as natural castles and lived in them thousands years ago. The remnants of the ancient primitive buildings and tools were found in some craters.

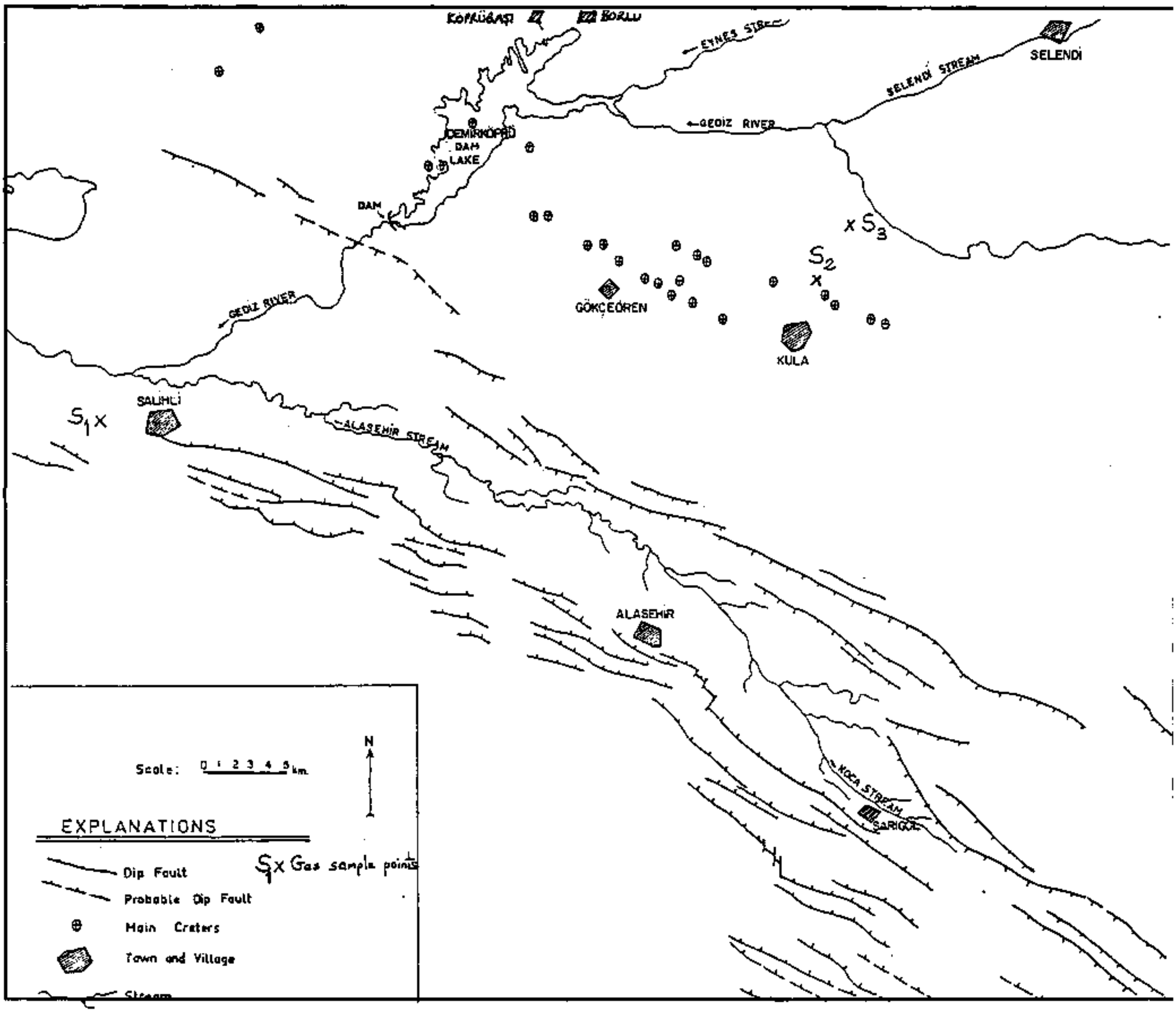
SAMPLE NO	KU 30 KULA DİVLİT T.	KU 31 KULA KARADİVLİT T.	KU 32 KULA KARAKUZ DERE	KU 34 KULA KÖFEKELLİ T.	KU 35 KULA DİVLİT T.	KU 38 KULA KÜÇÜK DİVLİT T.	KU 40 KULA DİVLİT T.	KU 44 KULA DİVLİT T.	KU 48 KULA DİVLİT T.	KU 49 KULA İLÇE	KU 50 KULA KARATAŞ	KU 63 KULA KONCAK T.	KU 95 KULA BAGHADA T.	KU 98 KULA ADALA KÖYÜ	KU 99 KULA SARAÇLAR KÖYÜ	KU 100 KULA GÖKÇEÖRE KÖYÜ
SiO_2	47.07	47.32	48.15	48.50	47.55	48.50	47.80	46.80	47.25	47.90	50.40	49.30	46.27	45.56	45.24	42.77
Al_2O_3	17.80	17.78	17.87	18.14	18.50	17.23	17.59	17.36	17.08	18.32	18.05	18.25	19.51	20.50	20.42	18.75
Fe_2O_3	2.98	2.41	3.56	3.81	4.32	3.92	5.01	8.70	4.24	2.21	2.55	1.96	2.76	2.39	2.39	3.63
FeO	4.85	5.08	5.36	4.99	5.07	5.57	3.97	1.60	4.69	5.71	4.86	6.34	5.61	5.70	5.70	6.13
MgO	5.57	5.79	6.60	5.90	5.80	6.30	5.50	5.30	5.70	5.80	4.00	4.00	4.89	5.19	6.03	5.96
CaO	8.62	8.63	8.29	8.04	8.21	8.71	8.66	7.94	8.25	8.15	7.59	7.85	8.21	7.84	8.27	11.14
Na_2O	6.05	5.73	4.19	4.35	4.08	6.08	4.20	4.35	5.00	5.22	5.75	5.30	5.41	5.25	4.85	3.35
K_2O	3.28	3.31	2.55	2.58	2.58	2.68	2.78	2.78	3.35	3.45	3.60	3.30	3.50	4.10	3.95	2.38
H_2O	0.58	0.65	0.46	0.07	0.51	0.34	0.20	0.79	0.25	—	0.02	0.08	0.10	—	—	1.86
TiO_2	2.11	1.99	1.75	1.80	2.00	1.89	1.90	1.86	1.85	1.89	1.76	1.85	1.80	2.10	2.00	2.63
P_2O_5	0.97	0.83	0.90	0.72	1.02	0.88	0.96	0.94	0.98	0.88	0.84	0.99	0.51	0.65	0.63	0.90
MnO	0.16	0.15	0.16	0.15	0.17	0.25	0.16	0.18	0.18	0.16	0.15	0.16	0.99	0.61	0.56	0.43
CO_2	—	—	0.28	0.44	0.44	0.44	0.28	0.39	0.50	0.27	0.38	0.42	—	—	—	—
TOPLAM (Total)	100.04	99.67	100.12	99.59	100.35	98.79	99.01	98.99	99.32	99.96	99.95	99.80	99.56	99.89	100.04	99.93
Q	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Or	19.37	19.62	15.05	15.90	15.78	16.03	16.59	16.59	19.93	20.39	21.28	19.54	20.77	24.25	23.33	14.07
Ab	10.53	10.34	24.19	25.80	25.40	20.26	24.85	25.76	18.11	14.13	22.95	22.61	6.68	2.20	0.96	5.48
An	11.72	13.06	22.39	22.14	24.16	21.04	21.14	19.83	14.36	16.37	12.81	16.29	18.69	20.28	22.27	29.11
Hy Fs	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hy En	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mt	4.32	3.50	5.15	5.54	6.24	5.75	7.33	0.35	6.19	3.20	3.70	2.85	4.02	3.47	3.46	5.76
Hm	—	—	—	—	—	—	—	8.54	—	—	—	—	—	—	—	—
Cc	—	—	0.63	1.00	0.99	1.01	0.64	0.89	1.14	0.61	0.86	0.95	—	—	—	—
Ap	2.29	1.97	2.13	1.71	2.41	2.11	2.29	2.25	2.33	2.08	1.99	2.35	1.21	1.54	1.49	2.13
Ne	22.01	20.75	6.07	6.04	4.88	7.95	5.98	6.19	13.26	16.28	13.93	12.09	21.29	22.90	21.70	12.39
OL Fo	4.42	5.10	9.17	8.10	8.54	8.19	6.18	6.49	6.15	6.91	3.73	4.78	5.23	6.39	7.70	6.27
OL Fa	1.14	1.69	2.65	2.02	1.79	2.49	0.15	—	1.14	3.08	1.73	3.84	3.28	3.36	3.52	2.19
Di Wo	10.31	10.21	4.61	4.33	2.92	5.87	5.90	4.70	7.19	6.94	7.08	5.67	7.88	6.01	6.10	8.47
Di En	7.56	7.18	3.32	3.20	2.21	4.19	5.01	4.06	5.50	4.58	4.63	3.15	4.76	3.81	4.01	5.90
Di Fs	1.77	2.15	0.87	0.72	0.42	1.16	0.11	—	0.92	1.85	1.95	2.30	2.69	1.81	1.66	1.87
IL	4.00	3.79	3.32	3.43	3.78	3.63	3.64	3.57	3.54	3.59	3.34	3.52	3.43	3.99	3.79	4.99
Al	16.02	16.05	16.06	16.39	16.60	15.70	16.00	15.78	15.48	16.50	16.25	16.46	17.64	18.46	18.36	16.88
Alk	12.35	11.94	8.82	9.24	8.77	8.90	9.17	9.39	10.91	11.28	12.22	11.27	11.66	11.99	11.22	7.40
FM	19.63	19.81	22.80	21.34	21.60	23.21	20.74	21.47	21.14	20.26	16.06	17.12	19.87	19.74	21.33	22.76
k	0.26	0.27	0.29	0.29	0.30	0.30	0.30	0.30	0.31	0.30	0.29	0.29	0.30	0.34	0.35	0.32
mg	0.12	0.14	0.29	0.28	0.30	0.27	0.27	0.25	0.17	0.18	0.14	0.18	0.20	0.21	0.24	0.39
P	38	40	48	48	47	46	47	45	41	42	42	43	42	41	42	46
RITTMANN'S NAME	Phonolitic Nepheline Tephrite	Phonolitic Nepheline Tephrite	Olivine Andesine Trachybasalt	Olivine Andesine Trachybasalt	Olivine Andesine Trachybasalt	Nepheline Tephrite	Olivine Andesine Trachybasalt	Nepheline Tephrite	Phonolitic Nepheline Tephrite	Phonolitic Nepheline Tephrite	Phonolitic Nepheline Tephrite	Phonolitic Nepheline Tephrite	Phonolitic Nepheline Tephrite	Phonolitic Nepheline Tephrite	Phonolitic Nepheline Tephrite	Nepheline Basanit
IRVINE & BARAGAR'S NAME	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Trachybazalt (Potassic)	Alkaline Basalt (Potassic)
N.P.C	19.88	22.52	39.48	38.17	41.89	38.56	37.78	35.47	26.32	28.41	21.72	27.59	30.72	33.44	37.49	52.59
N.C.I	24.20	24.30	24.91	23.43	23.29	25.94	23.22	23.67	24.21	23.73	19.59	20.67	23.83	23.23	24.60	27.21
D.I	51.92	50.72	45.32	47.75	46.06	44.25	47.43	48.54	51.31	50.81	58.17	54.25	48.74	48.36	46.00	31.95
S.I	24.51	25.94	29.65	27.15	28.42	27.94	25.63	23.32	24.80	25.90	19.27	19.14	22.08	22.93	26.31	27.79
σ	21.47	18.38	8.90	8.74	10.35	11.51	9.42	12.13	15.45	15.29	11.79	11.60	23.05	33.57	34.83	−164.33
τ	5.56	7.26	7.81	7.64	7.22	6.96	7.04	8.99	6.54	6.93	6.99	7.01	7.82	7.28	7.78	5.85
$\log \sigma$	1.33	1.26	0.95	0.94	1.01	1.06	0.97	1.08	1.19	1.18	1.07	1.06	1.36	1.52	1.54	—
$\log \tau$	0.74	0.86	0.89	0.88	0.86	0.84	0.84	0.84	0.81	0.84	0.84	0.84	0.89	0.86	0.89	0.76
$(FeO+Fe_2O_3)/SiO_2$	0.16	0.16	0.18	0.18	0.19	0.20	0.18	0.22	0.19	0.16	0.14	0.17	0.18	0.17	0.18	0.23
Al_2O_3/SiO_2	0.38	0.37	0.37	0.37	0.39	0.37	0.36	0.37	0.36	0.38	0.36	0.37	0.42	0.44	0.45	0.43
$Na_2O+K_2O/(Na_2O+K_2O+CaO)$	0.52	0.51	0.45	0.46	0.45	0.43	0.44	0.47	0.50	0.51	0.55	0.52	0.52	0.54	0.51	0.34
An.100/(Ab+An)	52.87	55.81	48.06	46.18	48.74	50.94	45.96	43.49	44.22	53.67	35.82	41.87	73.66	90.21	95.86	84.15
K_2O/Na_2O	0.54	0.57	0.61	0.61	0.65	0.65	0.66	0.64	0.67	0.66	0.62	0.62	0.64	0.72	0.81	0.71
SYMBOL	●															
ROCK GROUPS	KULA (DİVLİTTEPE) VOLCANICS (Qkv_3)															

Table 2. The results of the major element chemical analysis, the C. I. P. W. norms and the Rittmann parameters of Kula volcanics

Tablo 2. Kula volkanitlerinin majör element kimyasal analizleri, C. I. P. W. normları ve Rittmann parametreleri

Fig ur e 2. The Alaşehir-Salihli graben

Şekil 2. Alaşehir-Salihli grabeni



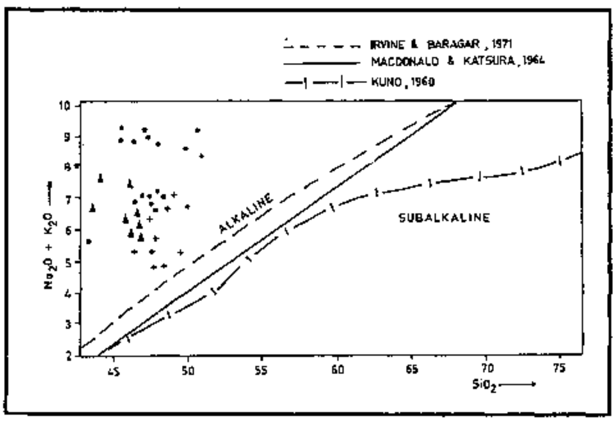


Figure3. Classification of the volcanics according to their alkali-silica content

Şekil 3. Volkanitlerin alkali-silika kapsamlarına göre sınıflandırılması

Furthermore, pirimitive human footprints that were Formed on the basaltic tuffs of the third stage volcanism have been found near the Lake of Demirköprü Dam, and the sample of the footprints are exhibited in some museums of the world. These footprints are the fourth discovery in the world , and according to Tekkaya (1976) they are 12.000 years old. Erinç (1970) suggested that the last stage volcanism had stardet 10.000 years ago. Ercan et al (1985) have found the ages of 30.000± 5.000 years and 25.000± 6.000 years for the youngest basaltic lavas by K/Ar method. Göksu (1982) has found 26.000±5.000 years by thermoluminecance method. According to these results the products of the last stage volcanism might have been formed approximately 10.000-30.000 years ago.

PETROGRAPHY

There is no petrographic difference between lavas of the three stages of Kula basalts after investigation of hundreds of samples collected in the studied area.

Kula basalt are well known in geologic literature. They were mentioned for first time by Washington (1894 and 1900). This author named them as "Kulaite"

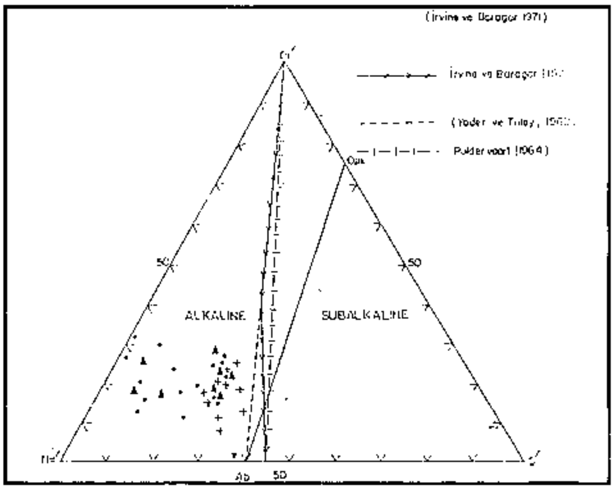


Figure 4. Classification of Kula volcanics according to the Ol´ - Ne´ - Q´ triangular diagram

Şekil 4. Kula volkanitlerinin Ol´ - Ne´ - Q´ üçgen diyagramına göre sınıflandırılması

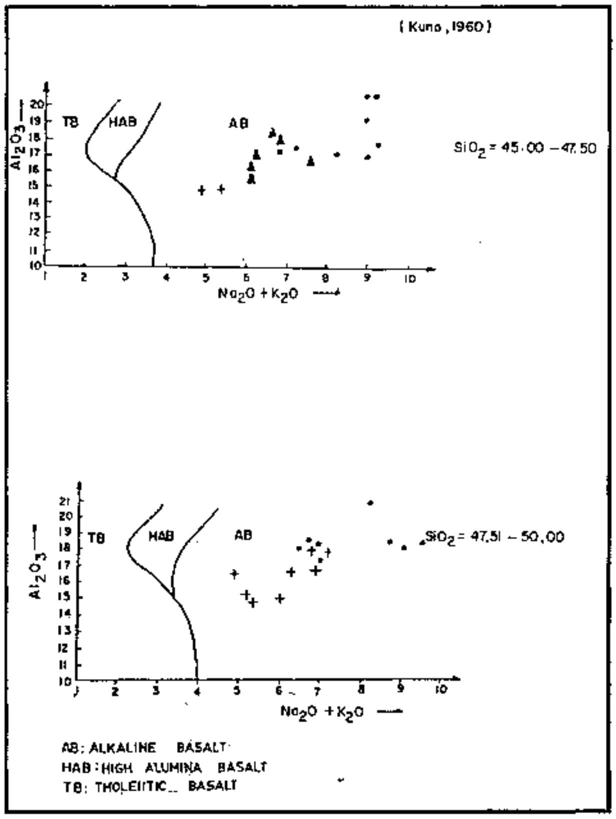


Figure 5. Kuno (1960) diagram of Kula basalts

Şekil 5. Kula bazaltlarının Kuno (1960) diyagramı

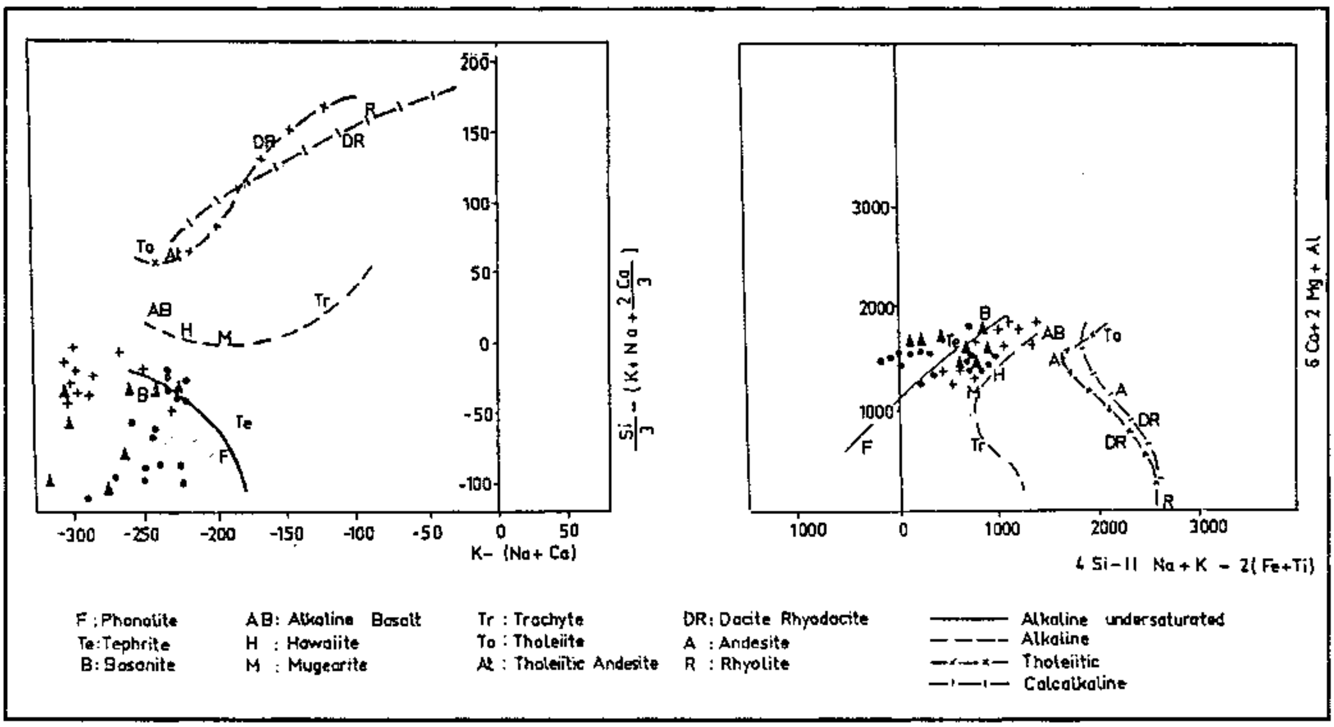


Figure 6. H. de la Roche (1978) diagram of Kula basalts

Şekil 6. Kula bazaltlarının H. de la Roche (1978) diyagramı

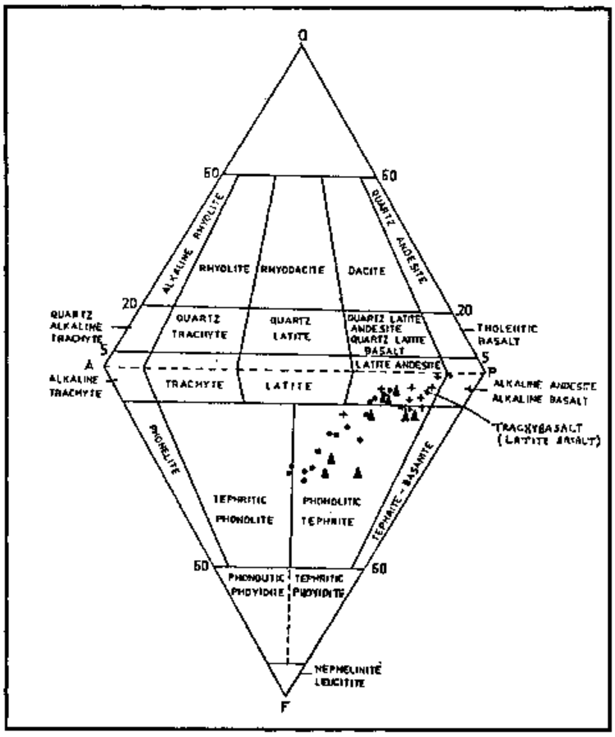


Figure 7. Nomenclature of the basalts according to the Streckeisen (1976) bi-triangular diagram

Şekil 7. Bazaltların Streckeisen (1976) çift üçgen diyagramına göre adlandırılması

SAMPLE NO	KU 89 ..$_I$	KU 84 A$_I$	KU 89 B$_I$	KU 84 B$_I$	KU 89 C$_I$	KU 84 C$_I$
La	37,5	71	63,7	68	47,8	90
Ce	73,8	139	122,7	145	87,?	150
Nd	33,1		51,3		34,1	
Sm	6,28		8,81		6,22	
Eu	1,98		2,69		2,04	
Tb	0,72		0,89		0,78	
Yb	1,96		2,35		2,28	
Lu	0,29		0,36		0,33	
Cr	179	47	102	45	47,7	51
Co	34,9	33	34,4	31	26	32
Ni	83,9	47	90,1	18		56
Sc	24,5	21	18,8	19	14,9	20
Rb	60,2	79	51,5	78	105	80
Sr	931	946	1302	868	1038	961
Ba	553	897	983	758	844	930
Sb			0,3		0,18	
As	5,33	5		14		5
Cs	0,96		1,11		1,17	
Zr	143	234	259	205	292	242
Hf	4,0[illegible]		5,38		4,6	
Ta	3,78	8	6,21	7	5,49	6
Zn	77,3		66,8		79,5	
Th	5,75	10	8,43	12	7,95	13
U	1,59	5	2,3	3	1,96	5
V		171		190		168
Cu		61		38		56
Mo		16		8		9
Nb		88		67		87
Pb		5		14		5
Y		34		30		34
$^{87}Sr/^{86}Sr$	0,70346	0,70342	0,70329	0,70299	0,70307	0,70315
ROCK GROUPS	KULA (BURGAZ) VOLCANICS Qkv_1		KULA (ELEKÇİTEPE) VOLCANICS Qkv_2		KULA (DİVLİTTEPE) VOLCANICS Qkv_3	
SYMBOLS	●	○	▲	△	■	□

Table 3. The results of the trace element chemical analysis and Strontium isotopic ratios of Kula volcanics

Tablo 3. Kula volkanitlerinin iz element kimyasal analizleri ve Stronsiyum izotop oranları

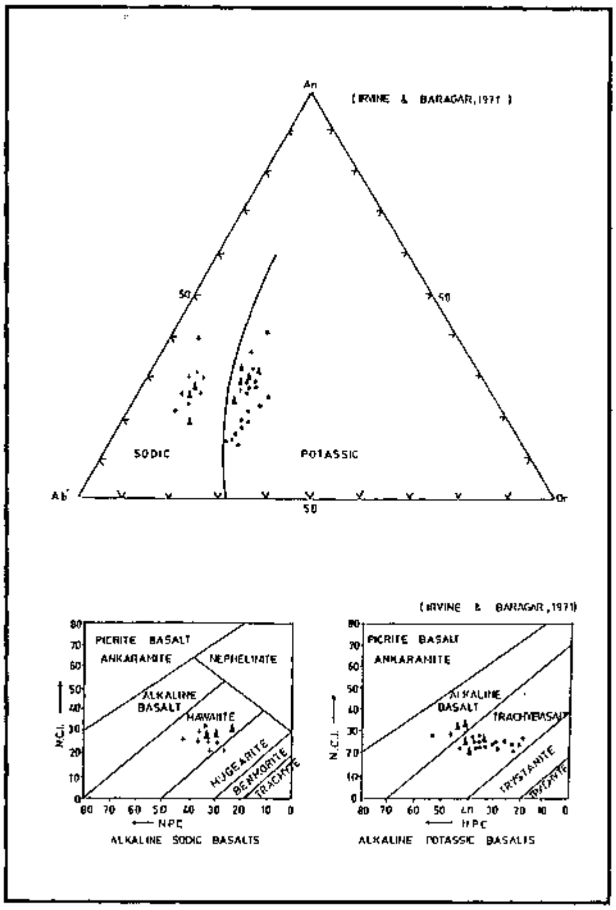


Figure 8. Irvine and Baragar (1971) classification of Kula basalts

Şekil 8. Kula bazaltlarının Irvine ve Baragar (1971) 'a göre sınıflandırılması

and pointed out that they are hornblend, nepheline, plagioclase and olivine basalts. Later, Borsi et al. (1972) proposed that these rocks are "Nepheline trachyandesite" according to Coombs and Wilkinson (1969) classification. Petrographic and petrochemical nomenclation of the lavas have some problems. There is not any international confirmation on classification of these volcnic rocks yet. The same lavas were differently named.

The lavas arc black, dark grey, grey, red and vesicular. Generally show porphyritic or hyalophyritic texture in a groundmass chiefly consisting of glass, plagioclase microlites, abundant micro crystals of augite, olivine, hornblende, hyperstene, nepheline, leucite, analcime, apatite, magnetite, orthoclase and mafic minerals. The principal phenocrysts are of abundant augite, titanaugite, olivine and hornblende. The phenocrysts of ilmenite, plagioclase, nepheline, epidote, leucite occur in less abundance. Hornblende phenocrysts are of basaltic hornblende and syntagmatite (kersutite), and have been altered. Plagioclase Phenocrysts are of generally labradorite, anorthite and less Frequently andesine, oligoclase and bitovnite in composition. Quarts xenocrysts are observed in some thin sections. The olivine phenocrysts are also partly uralitized.

All the lavas are named as "alkali olivine basalt" in general. According to results of petrographic investigation the lavas named as hornblende-pyroxene basalt, ilmenite-olivine basalt, hornblende-olivine basalt, ilmenite-pyroxene basalt, nepheline basalt, hornblende-augite basalt, olivine bearing hornblende-pyroxene basalt, hyperstene-pyroxene basalt and olivine-pyroxene basalt.

In addition to petrographic investigations on basaltic lavas, same type petrographic studies have been carried out from the samples of the mantle xenoliths in the second and third stage lavas. Abundant mantle xenoliths were brought up by the eruptions of the second and third volcanic activity periods. These xenoliths consist of olivine, kaersutite, apatite, cpx (Augite and titanaugite), and rarely phlogopite and sphene.

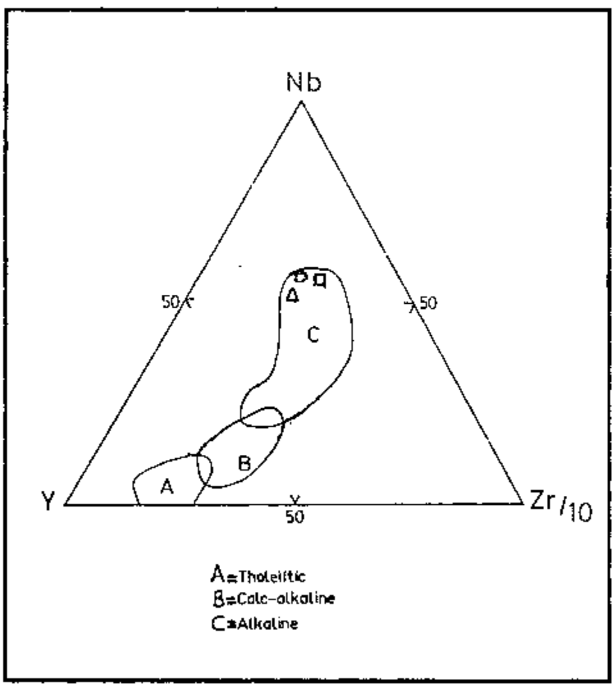


Figure 9. Whitehead and Goodfellow (1978) triangular Nb - Y - Zr/10 diagram of Kula basalts
Şekil 9. Kula bazaltlarının Whitehead ve Goodfellow (1978) üçgen diyagramı

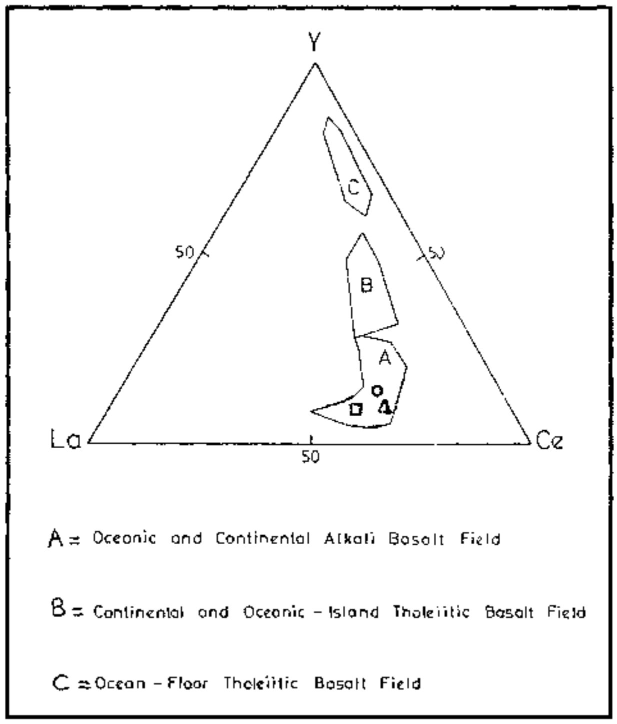


Figure 10. Ricci and Serri (1975) triangular Y - La -Ce diagram of Kula basalts
Şekil 10. Kula bazaltlarının Ricci ve Serri (1975) üçgen diyagramı

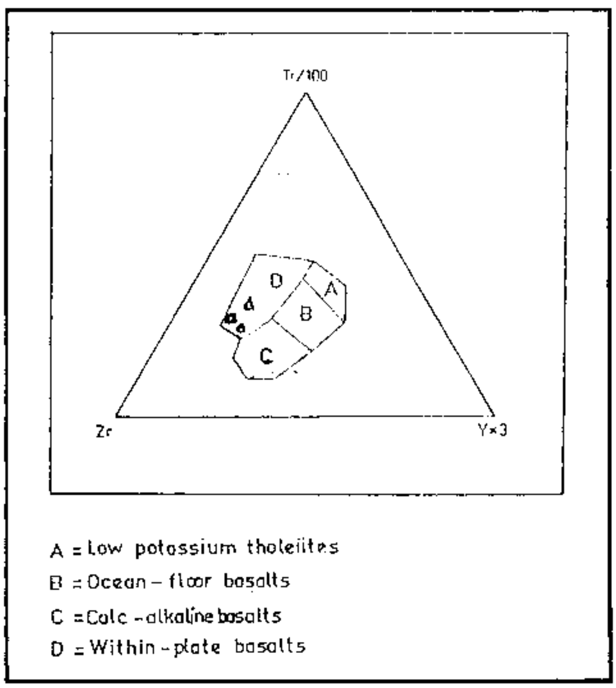


Figure 11. Pearce and Cann (1973) diagram for the rock samples according to their Ti - Zr - Y contents
Şekil 11. Kayaç örneklerinin Ti - Zr - Y kapsamlarına göre hazırlanan Pearce ve Cann (1973) diyagramı

PETROCHEMISTRY

A) The results of the chemical analyses of the major elements

Eleven samples of the first stage, eight samples of the second stage and sixteen samples of the third stage were selected for wholerock chemical analysis of major element (Table 1 and 2). Results of the chemical analysis was programmed for computer and various parameters of the volcanics were calculated. Later, those parameters were applied on various graphs and the characters of the volcanics were investigated by a chemical method.

C. I. P. W. norms of the lavas show us unsaturations of silica. Olivine (mostly as forsterite) and nepheline are seen on the C. I. P. W. norm calculations. They also point out to the deficiency of silica. There is no modal hyperstene and diopside is comprised generally in wollastonite. Magnetite is present in all samples and hematite is present in some samples.

Besides the results of the petrographic investigations the results of the chemical analyses and the C. I. P. W. norm demonstrate that Kula lavas are alkalic in character.

The Rittmann parameters of the lavas which are necessary for Rittmann nomenclature (1952 and 1962) were calculated. These parameters were used on Rittmann diagrams and the samples were classified. Kula lavas are classified as phonolitic nepheline tephrite, nepheline tephrite, nepheline basanite, andesinc basalt, olivine andesine trachybasalt according to Rittmann classification (Table 1 and 2).

The results of the chemical analysis of the lavas and various parameters wich were calculated by computer were applied on various graphs and the results are as follows:

a) Kula volcanics are alkalic according to SiO_2/Alk. ($Na_2O + K_2O$) diagram (Fig. 3).

b) Alkaline character of the volcanics were confirmed by Ol'- Ne' - Q' triangle diagram (Fig. 4). All the samples are placed the alkaline area of the diagram which was offered by Irvine and Baragar (1971).

c) It was pointed out that Kula lavas are alkali basalts according to Kuno (1960) diagram which was arranged considering their AI2O3, *(N^O* + K2O) and SİO2 contents (Fig. 5).

d) The Rittmann indices of Kula lavas [d = $(Na2O + K_2O)^2 / (SİO2 - 43)$] change between 4, 21-155, 52. Their mean value is around 10 and this indicates that the Kula basalts are strongly alkaline, d Values of the first stage lavas are the lowest and the alkaline ratios of the lavas become higher towards the third stage. Furthermore, the lavas grade into more potassic from the oldest stage to the youngest one.

e) Differentiation indices of the Kula lavas were also calculated. The D. I. indices of Kula volcanics (according to Thornton and Tuttle, 1960) vary from 31, 95-58,17. They are lower in the first stage lavas and higher in the third stage. The mean index value is about 46. Le Maitre (1976), calculated the mean D. I. of the basalt family lavas in the world according to statistical researches. Therefore it is realized that Kula lavas are tephrite, trachybasalt and hawaiite in nature according to their D. I. values. Additionally the diagram of variation of major elements versus D. I. values were plotted. It shows that the increase of D. I. values is dependent on the increase of SİO2, K2O, Na2O, AI2O3 contents and the decrease of CaO, MgO, TİO2 and total Fe oxide contents. These pecularities conform with the variations which Thornton and Tuttle (1960) offered. Thus, it was proved that basaltic magma has a normal crystallization stage.

f) H. de la Roche (1978) chemical parameters of the volcanics were calculated as well. By using the values of K - (Na + Ca), Si/3 - (K + Na + 2Ca/3), 6Ca + 2Mg + Al, 4Si - IINa + K - 2(Fe + Ti) on the graphs it is once more confirmed that Kula lavas are Hawaiite, Tephrite and basanite according to chemical characteristics (Fig. 6).

g) Kula lavas can also he named as latite basalt (Trachybasalt), phonolitic tephrite, tephritic phonolite, alkaline basalt by using Streckeissen (1976) pair triangle diagram (Fig. 7).

h) The Irvine and Baragar (1971) classification is also applied to Kula lavas (Fig. 8). The An - Ab' - Or triangle diagram was plotted in order to distinguish the sodic lavas and potassic ones. N. P. C. and N. C. I. parameters which were calculated by computer were used on these diagrams. It was confirmed that alkali sodic Kula lavas can be named as Hawaiite (one of them is Mugearite), and alkali potassic Kula lavas can be named as alkali basalt and trachybasalt.

The results obtained by scattering the results of the major element analyses of the Kula lavas on the graphs can be summarized as follows:

I- There is no chemical difference between the lavas of all three stages and all the lavas are strongly alkaline. They have derived from an alkali olivine basaltic magma and have a mantle origin.

II- The lavas are partly sodic and partly potassic. Their potassium content increase from first to third stage. The younger lavas arc more potassic then the old ones.

III- Lavas have various names according to methods which were offered by various investigators. Regarding all nomenclatures Kula lavas which had been

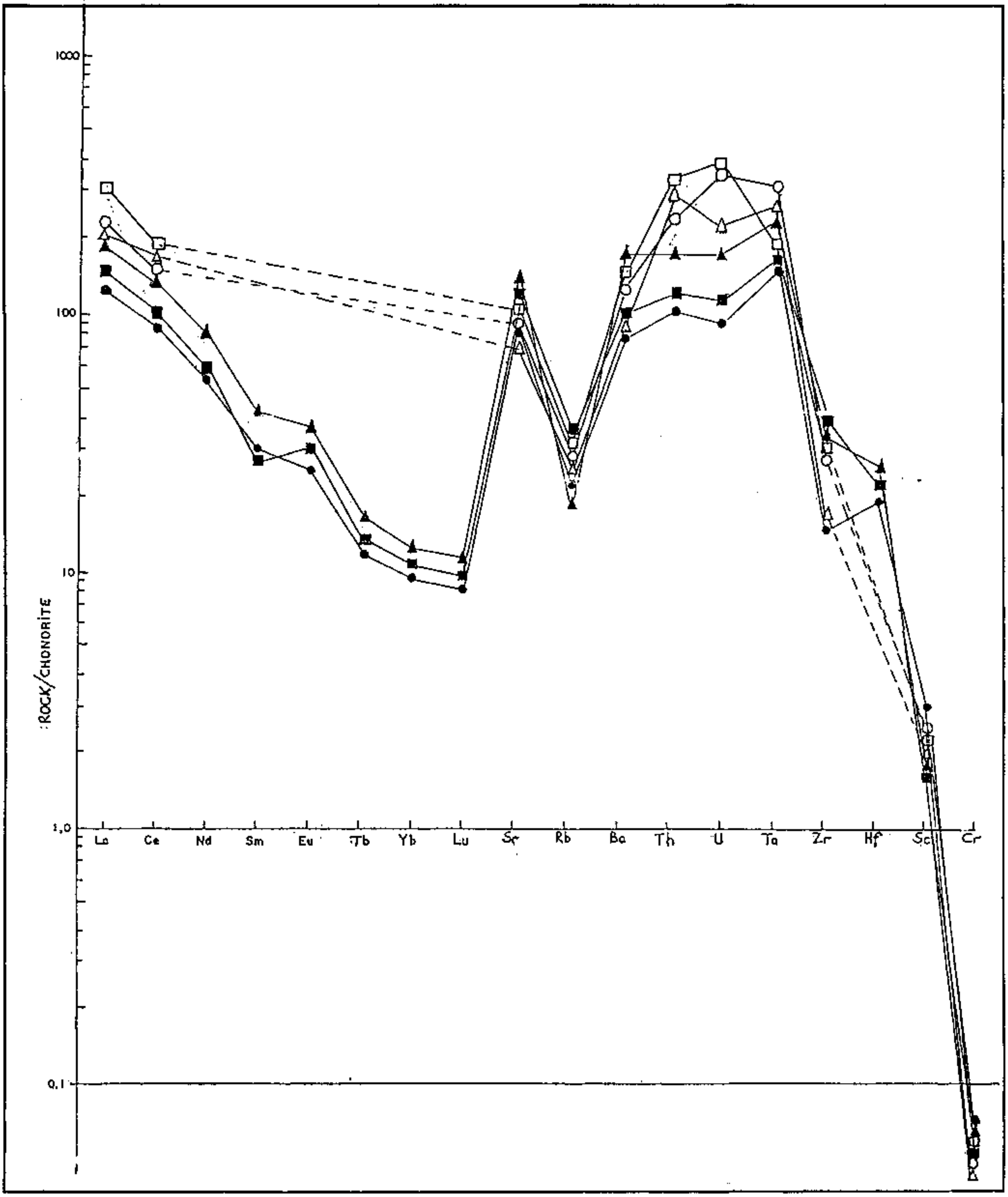


Figure 12. Chondrite-normalizcd trace elements and REE patterns of Kula basalts

Şekil 12. Kula bazaltlarının kondritlere göre normalize edilmiş iz ve nadir toprak element kapsamları named as "Kulaite" by Washington (1894 and 1900) long time ago, generally can be named as Hawaiite and trachybasalt and secondly can be named as tephrite and mugearite. Sodic lavas are Hawaiite and potassic lavas are trachybasalt in nature. The potassium amount increases from the oldest lavas to the younger ones.

B) The results of the chemical analyses of the trace elements

Trace element chemical analyses and the measurements of the isotopes of strontium, neodmium and lead of the samples taken from all three stages of Kula basalts were carried out in various laboratories. Trace element contents as ppm and the results of the strontium isotope ratios are presented in table 3. Chemical analysis of the samples KU 89, Aj, Bj and Cj were made by Dr. Fujitani in Japan in 1989. The analysis of the samples KU 84 Aj, Bj and Cj were made in Germany (Ercan et al., 1985).

Twenty-Four trace elements including rare-earth in three volcanic rocks in Kula were determined by instrumental neutron activation analysis (INAA) in Japan. Neutron activation was carried out at the research reactor of Kyoto University (KUR) and JRR-4 of Japan Atomic Energy Research Institute. After sample irradiation, the counts of gamma-ray were done twice with the interval for appropriate cooling by two pure Ge semi-conductor detectors. They were coupled to a 4096 channel pulse height analyser and controlled by a personal computer. Analysed results are tabulated in table 3 and the results were obtained are as follows:

a) Triangular diagram proposed by Whitehead and Goodfellow (1978) according to Nb-Y-Zr contents of the samples were plotted and were proved to be alkaline by their trace element contents (Fig. 9).

b) Triangular diagram proposed by Ricci and Serri (1975) according to Y-La-Ce contents of the samples were plotted (Fig. 10) and were recognized to have fallen on the alkali basalt field.

c)Pearce and Cann (1973) diagram arranged according to Ti-Zr-Y contents of the samples were plotted (Fig. 11) and were recognized that they fell on the within plate basalt field.

d) Normalized diagram according to chondrites by using trace element contents of the samples was plotted (Fig. 12) and was defined thad they have mantle origine. Their REE patterns display similar characteristics that light REE are enriched over heavy REE. They have positive Eu anomaly.

C) Results of the isotopic measurements

Isotopic measurements were also carried out on Kula volcanics. Strontium isotopic compositions of the same rocks were determined by Dr. Notsu on a multi-collector-type mass spectrometer at Tokyo National Research Institute of Cultural Properties (Japan). These results are also tabulated in Table 3.

a) Strontium isotope ratios (87 Sr/ 86 Sr) of Kula volcanics are between 0.70299 - 0.70346. These low values indicate a mantle origin. Borsi et al. (1972) have formerly found a lower value of 0,7020. Moreover, strontium isotop ratios of Kula basalts decrease in time. Strontium isotopic ratio of the youngest basaltic lavas of the third stage is lower than the ratios of the other stages. This can be interpreted as the evidence of the increasing effects of the mantle in forming basalts.

b) Abundant mantle xenolits were brought up by the eruptions of the second and third volcanic activitiy periods. These xenoliths consist of olivine + kaersutite + apatite + cpx ± phlogopite ± spene indicating modal metasomatizm of the subcontinental lithosphere according to Gülen at al. (1986).

c) Other isotopic ranges for Kula basalts are:

$^{143}Nd/^{144}Nd$ =0,513066-0,512905

$^{206}Pb/^{204}Pb$ = 18.684 - 19.014

$^{207}Pb/^{204}Pb$ = 15.570 - 15.647

$^{208}Pb/^{204}Pb$ = 38.412 - 38.835

Kaersutite, phlogopite and apatite mineral separates from a xenolilh have identical $^{87}Sr/^{86}Sr$ = 0,70340 and $^{143}Nd/^{144}Nd$ = 0,512870. Having the near equality in $^{87}Sr/^{86}Sr$ for the apatite and phlogopite pair costrains maximum age of metasomatism or the age of the complete isotopic equilibration as being < 500.000 years. Based on this isotope data one can construct a number of mantle source region models. However, any plausible model has to involve: I) A mantle that has had a time-integrated depletion in Rb / Sr, Nd / Sm and Pb / U as has MORB source and II) Either a recent metasomatism of this mantle by a CO_2 and LREE-enriched fluid or a mixture of components from this mantle with components from an overlying, previously-metasomatised subcontinental mantle (Gülen et al., 1986).

NOBLE GAS AND HELIUM ISOTOPIC COMPOSITIONS IN GAS SAMPLES IN KULA AREA

Gas samples were taken from hot springs in three diferent points of Kula region. Sample locations are shown in Fig. 2. Gas samples were bubble gases

Table 4. $^3He/^4He$ ratios and noble gas elemental compositions of bubble gases from Kula area.
Tablo 4. Kula yöresinden alman gaz örneklerinin $^3He/$ 4jj$_e$ oransallıkları ve asal gaz elemental bileşimleri

Sample No and Location	Temperature of Water (°C)	$^3He/^4He$ ($\times 10^{-6}$)	$^4He/^{20}Ne$	(I) C(4He) (ppm)	F^m (2) ^4He	^{20}Ne	^{36}Ar	^{84}Kr	^{132}Xe
S_I(Salihli-Kurşunlu)	90°	I,75 ± 0,46	0,57	0,057	I,2	0,67	=I	I,8	2,7
S_2(Kula-Madensuyu)	I6°	3,92 ± 0,I5	28	23	33	0,38	=I	I,5	I,4
S_3(Kula-Emir)	57°	2,38 ± 0,06	I5	I7	49	I,I	=I	I,2	I,5

(I) Concentration of He in gas sample
(2) $F^m = (^mM/^{36}Ar)_{sample}/(^mM/^{36}Ar)_{air}$,where ^mM means $^4He, ^{20}Ne, ^{36}Ar, ^{84}Kr$ and ^{132}Xe

collected at the water poll in glass vessel. Sampling vessel was made of glass and its inside volume was about 100 cm.[3] Before the noble gas mass spectrometry the gas samples in the glass vessels were divided into several glass ampoules with brekable seal. Noble gas isotopic compositions were analyzed by a mass spectrometer which is of a single focusing 90° sector type with 30 cm. radius of ion curvature in Chemical Laboratory of Okayama University (Japan) by. Dr. Nagao.

Noble gas isotopic and elemental compositions obtained are listed in Table 4. Noble gas elemental and isotopic compositions are a useful indicator for a degassing process of fluid and gaseous materials from the solid earth. Helium isotopic ratios show especially wide variations according to their origin. In the mantle, the average ^3He / ^He ratio is 1,1x10 $^{-5}$; in atmosphere $^3He/^4He$ = 1,4X10"6 and in crust ^3He^He = 3x10"8 (Kamenskiy et al., 1976; Sano and wakita, 1985). $^3He/^4He$ ratios and elemental compositions of noble gases in the investigated area are presented in Table 4. The temperature of water in the table was measured at the site where the gas sample was collected $^3He/^4He$ ratio are higher than the atmospheric ratios and in the range of, I, 75-3, 92 in unit of 1(H> for Kula area, indicating mantle He in those gases. $^3He/^4He$ ratios of gas samples from Kula area are plotted against ^He/^Ne ratios in Fig. 13. And after the Fig. 14,^{3}He/^He ratios are plotted against the concentrations of He in gas samples. Wide variation of He concentrations from, 0,057 to 23 ppm were observed. Since the gases are mainly composed of CO_2, a different degree of dilution by CO_2 causes the wide variation of He concentration in gas samples. A weak positive correlation between $^3He/^4He$ ratios and concentrations found in Fig. 14 may be produced by dilution of magmatic He with small

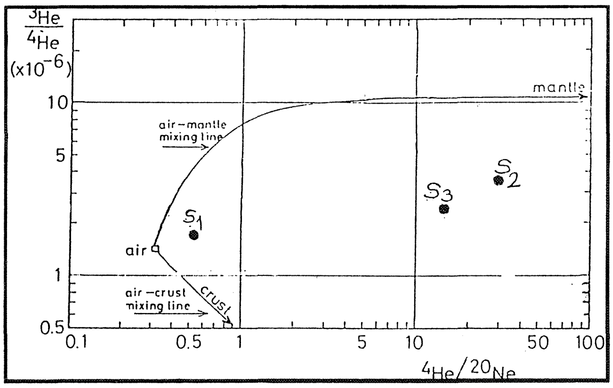


Figure 13. Correlation plot between $^3He/^4He$ and 4jj$_e$ /20jsj$_e$ f$_{or}$ g$_{as}$ samples from Kula area (The diagram model is taken from Nagao et al., 1989)

Şekil 13. Kula yöresinden alman gaz örneklerinin $^3He/^4He$ ve $^4He/^{20}Ne$ ilişki diyagramı (Diagram modeli Nagao ve diğerleri, 1989'dan alınmıştır)

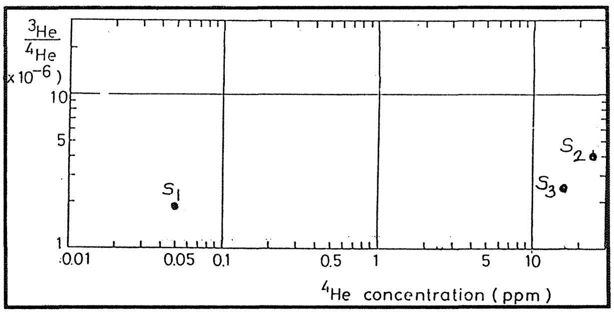


Figure14. ^{3}He/^Herations are plotted against ^{4}He concentrations of gas samples from Kula area (The diagram model is taken from Nagao et al., 1989)

Şekil 14. Kula yöresinden alman gaz örneklerinin $^3He/$ ^He oransallıklarına karşı 4He konsantrasyonu diyagramı (Diyagram modeli Nagao ve diğerleri, 1989'dan alınmıştır) quantity of radiogenic ^He released with CO_2 from marine carbonate in the crust. Because of a low content of uranium and thorium in carbonate the ratio of radiogenic ^He to CO_2 released is low and the He concentration becomes low by dilution.

Noble gas elemental abundance pattern is shown by F^m in Fig. 15. F^m, which indicates the difference between noble gas relative abundances normalized to ^{36}Ar in sample and those in atmosphere, is defined as follows:

$$F^m = (^mM / ^{36}Ar)_{sample} / (^mM / ^{36}Ar)_{air}$$

where ^mM is an isotope of mass "m". The abundance pattern of Ne, Ar, Kr and Xe in the samples are similar to that found in water saturated with atmospheric noble gases. Hence these noble gases may be recycled atmospheric noble gases released from

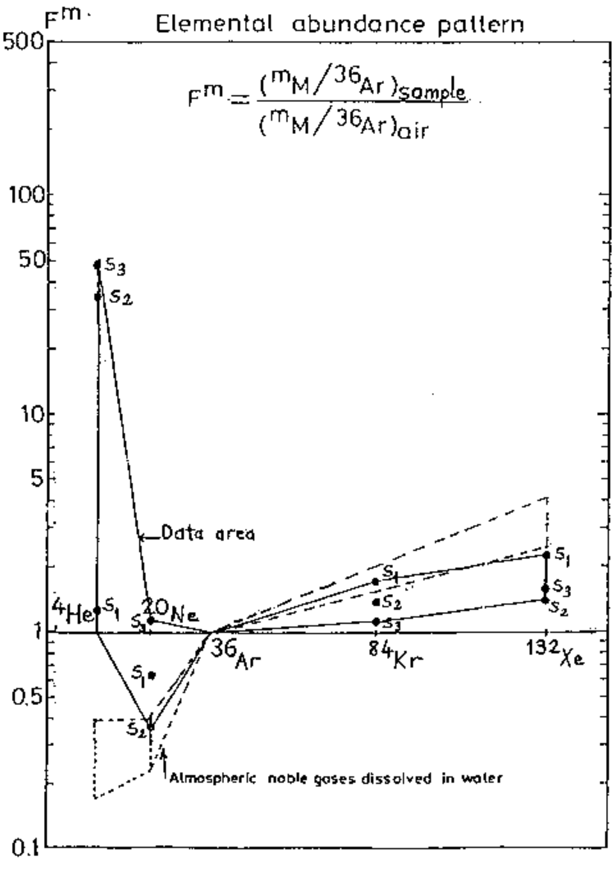


Figure 15. **Elemental abundance pattern of noble gases defined by Fm for gas samples from Kula area (The diagram model is taken from Nagao et al., 1989)**

Şekil 15. Kula yöresinden alınan gaz örneklerindeki asal gaz kapsamlarının elemental bolluk dağılımları (diagram modeli Nagao ve diğerleri 1989'dan alınmıştır)

ground water. He enrichments in most of the samples can be attributed to the contribution of mantle and crustal He to these samples in Fig. 13.

CARBON ISOTOPIC RATIOS IN GAS SAMPLES IN KULA AREA

Carbon dioxide in gas sample was purified for isotope measurement as follows. An apporpriate amount of gas sample was taken into the vacuum line. Carbon dioxide and H_2O were separated from noncontensible gases by using liquid N_2 traps. Carbon dioxide was seperated from H_2O by fractional distillation at the temperature of acetone-dryice sherbet and introduced into the mass spectrometer (MAT 250) for isotope measurement in the Chemical Laboratory of Akita University (Japan) by Dr. Kita.

The isotopic compositions ($^{13}C/^{12}C$) are reported in the conventional $d^{13}C$ notation as follows:

$$d^{13}C = [(^{13}C/^{12}C)_{sample} / (^{13}C/^{12}C)_{standart} - 1] \times 10^3, ‰$$

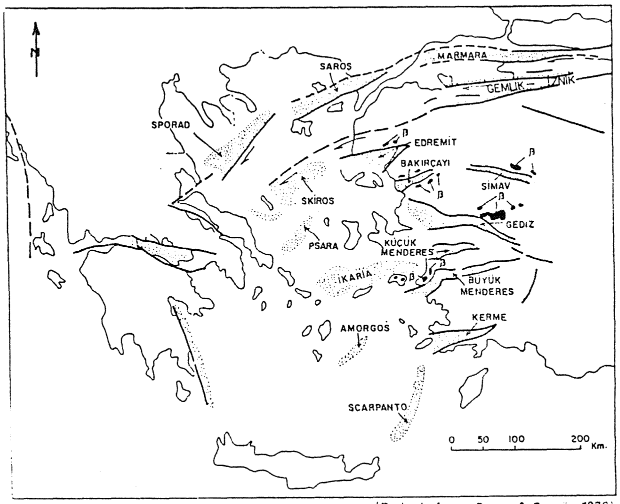
where the standard is PDB (Belemnitella Americana from the Cretaceous Pedee formation, South Carolina).

The chemical and isotopic compositions of gas samples are show in Table 5. Main component was CO_2. $d^{13}C$ values (-6, 61 to -5, 04 ‰) of CO_2 collected in sampling sites in Kula area. These values suggest that the carbon dioxide has a mantle origin. Carbon isotopic ratios are also useful indicators for the origin of materials. The naturally occurring variations of carbon isotopic compositions are greater than 10% (neglecting meteoritic carbonate). Heavy carbonates with $d^{13}C$ values of more than + 20‰ and light methane with values as low as -90‰ have been reported in literature. $d^{13}C$ variations of some important carbon compounds are -40 to -20‰ in sedimentary organic material, petroleum and coal; -30 to -10‰ in marine and non marine organism; -10 to -5‰ in carbonatites and diamonds; -8 to -4, 1‰ in mantle origine CO_2. Thus, carbon isotopic ratios in gas samples in Kula area suggest that the carbon dioxide has of mantle origin.

Sample No and Location	H_2 (ppm)	CH_4 (ppm)	CO_2 %	$\delta^{13}C$ (CO_2) ‰
S_1 (Salihli-Kurşunlu)	12	55	82	-5,23
S_2 (Kula-Madensuyu)	Air level	Air lev.	74	-6,61
S_3 (Kula-Emir)	Air level	Air level	76	-5,04

Table 5. **Chemical and isotopic compositions of bubble gases from Kula area**

Tablo 5. **Kula yöresinden alınan gaz örneklerinin kimyasal ve izotopik bileşimleri.**



(Revised from Dewey & Şengör 1979)

Figur e 16. The Graben system of western Anatolia
Şekil 16. Batı Anadolu'daki graben sistemi

DISCUSSION

The studied area is in the north of Alaşehir-Salihli (Gediz) graben and it is clear that volcanism is related to that graben system (Fig. 2). If all grabens in western Anatolia are considered it will be realized that they have been active since Middle Miocene (Fig. 16). Some investigators (Dewey and Şengör, 1979; Şengör, 1980; Yılmaz, 1990) suggested that in eastern Anatolia, Aegean -Anatolian plate and Arabic plate started to collide in Middle Miocene and as a result of that collision, compressional tectonics dominated in the region. After collision and crustal thickening, East Anatolian and North Anatolian transform faults were developed in the progressive stages of the compression according to plate tectonic model of Turkey by Ketin (1977). The Aegean-Anatolian plate had started to be pushed along the East Anatolian and North Anatolian transform faults towards to the west. Westward moving Aegean-Anatolian plate met the Africa plate in the west of Greece. For African plate hindered the move of Aegean-Anatolian plate (Şengör, 1980) an E-W compression occured in all Aegean sea and western Anatolia. This compression began to be progressively relieved by N-S extension which has governed most of the following tectonic evolution of Western Anatolia since Middle Miocene. Under the extensional regime about nine E-W trending grabens formed in the Aegean region as the most prominent structural and morphological features. Thus, it was concluded that Kula alkali basaltic lavas which were formed from a plume shaped mantle generated from a hot spot of the mantle reached to the surface via the fracture system of Alaşehir-Salihli graben which was originated together with the other grabens of Western Anatolia. This volcanism had its source in a parti metasomatized mantle. All of the geochemical and isotopic results proved that volcanism has a mantle origine. So, mantle gave rise to typical rift-type basalt (much like beneath active rifts where mantle has played a passive role in rifting; e. g. the volcanism of the upper Rheine Graben). According to Yılmaz (1990), in Western Anatolia, the rift induced alkaline basaltic volcanism shows wider diversity in geochemical variations and it is related to the heterogeneous source region which has partialy been metasomatised prior to the opening of the rift due to the reasons outlined above. The rift system in Western Anatolia is recently active and according to the theory of plate tectonics it will continue for a while. Noble gas, helium and carbon isotopic composition in gas samples from Kula volcanic province were measured and mantle-derived helium and CO_2 was found in all the recent samples in this investigation. Therefore, it is possible that the Kula volcanism will be re-active and new alkali basaltic lavas will be formed in future. Therefore, it is time to make instrumental volcanologie investigations in the Kula region.

BIBLIOGRAPHY

Borsi, S., Ferrara, G., Innocenti, F. and Mazzuoli, R., 1972, Geochronology and petrology of recent volcanics in the Eastern Aegean sea: Bull. Volcan., 36/3, 473-496

Coombs, D.S. and Wilkinson, J. F. C, 1969, Lineages and fractionation trends in undersaturated volcanic rocks from the East Otago volcanic province (New Zealand) and related rocks: Jour, of Petrology, 10/3, 440-501

Deleuil, A., 1977, Contribution a la geochronologie potassum argon du volcanisme Neogene d' Anatolie occidentale (regions de Kızılcahamam et de Uşak, Turquie): These, Toulouse Paul Sabatier Univ., France, 85 p.

Dewey, J. f. and Şengör, A. M. C, 1979, Aegean and surrounding region, complex multi plate and continuum tectonics in a convergent zone: Geol. Soc. Amer. Bull., 90,84-92

Ercan, T., 1981, Geology of the Kula area (West Anatolian, Turkey) and petrology of the volcanic rocks: These, İstanbul, Univ., İstanbul, 168 p.

Ercan, T. .nul Ö/tunalı, Ö., 1982, Characteristic features and iki-o Surge" bed forms of Kula volcanics: Bull. Gicol. Soc. Turkey, 25, 117-125

Ercan, T., Satır, M., Kreuzer, H., Türkecan, A., Günay, E., Çevikbaş, A., Ateş, M., and Can, B., 1985, Interpretation of new chemical, ısotopic and radiometric daha on Cenozoic volcanics of Western Anatolia: Bull. Geol. Soc. Turkey, 28, 121-136.

Erinç, S., 1970, Kula-Adala arasında gene volkan relief i: î. Ü. Coğrafya Ens. Derg., 17, 148-167

Göksu, Y., 1982, Gediz kıyısındaki ayak izleri kaç yaşında?: 25/12/1982 tarihli Cumhuriyet Gazetesi, 2.

Gülen, L., Hart, S., and Ercan, T., 1986, Metasomatised mantle below Western Turkey: A Sr-Nd-Pb isotopic study of alkaline magmas and mantle xenoliths: Terra Cognita, 6/2, 241.

H. De La Roche, H., 1978, La chimie des roches presentee et interpretas d'apres la structure de leur fades mineral dans L'espace des variables chimiques: Chemical Geol., 21, 63-87

Hoefs, J., 1980, Stable isotope geochemistry, Springer-Verlag

Irvine, T. N. and Baragar, W. R. A., 1971, A guide to the chemical classification of the common volcanic rocks: Can. Jour. Earth Scien., 8, 523-548

Kamenskiy, I. L., Lobkov, A., Prasolov, E. M., Beskrovny, Y., Kudrayavtseva, E. I., Anufriyev, G. S. and Pavlov, V. P., 1976, Components of the upper mantle in the volcanic gases of Kamchatka according to He, Ne, Ar and C isotopy: Transl. from Geokhimiya, 5, 682-694

Ketin, İ., 1977, Genel Jeoloji, Cilt I, Yerbilimlerine giriş: İst. Tek. Üniv. yayın,1096, 597 p.

Kuno, H., 1960, High-Alumina basalt: Journal of Petrology, I, 121-145.

Le Maitre, R.W., 1979, The chemical variability of some common igneous rock,: Journal of Petrology, 17/4, 589-637

Macdonald, G. A. and Katsura, J., 1964, Chemical composition of Hawaiian lavas: Journal of Petrology, 5, 82-133

Nagao, K., Matsuda, J. L, Kita, 1. and Ercan, T., 1989, Noble gas and carbon isotopic compositions in Quaternary volcanic area in Turkey: Bull. Geomorp., 17, 101-110

Pearce, J. A. and Cann, J. R., 1973, Tectonic setting of basic volcanic rocks determined using trace element analysis: Earth Planet. Scien. Lett., 19, 290-300

Ricci, C. A. and Şerri, G., 1975, Evidence geochimiche sullo diversa affinita petrogenetica delle rocce basiche comprese nelle seric a facies Toscana: Boll. Soc. Geol. Ital., 94, 1187-1198

Rittmann, A., 1952, Nomenclature of volcanic rocks: Bull. Volcan., 14, 75-102

Rittmann, A., 1962, Volcanoes and their activity: John Wiley and sons, New York, London, 305 p.

Sano, Y. and Wakita, H., 1985, Geographical distribution of 3He / 4He ratios in Japan,; Implications for arc tectonics and incipient magmatism: Jour. Geophys. Res., 90, 8729-8741

Streckeissen, A. L., 1976, Classification of the common igneous rocks by means of their chemical composition, A provisional attempt: N. Jb. Miner. Monats. 1976, 1-15.

Şengör, A. M. C, 1980, Türkiye'nin neotektoniğinin esasları: T. J. K. Yayını, 40p., Ankara

Tekkaya, İ., 1976, İnsanlara ait fosil ayak izleri: Yeryuvarı ve İnsan, 1/2, 8-10

Thornton, C, P. and Tuttle, O. F., 1960, Chemistry of igneous rocks, Part 1, Differentiation index: Amer. Jour. Scien, 258, 664-684

Washington, H. S., 1894, On the basalts of Kula: Amer. Jour. Scien, 48, 114-123

Washington, H. S., 1900, The Composition of Kulaite: Journal of Geology, 8, 610-620

Whitehead, R. E. S. and Good fellow, W. D., 1978, Geochemistry of volcanic rocks from the Tetagouche group, Bathurst, New Brunswick, Canada: Can. Jour. Earth. Scie., 15, 207-219

Yilmaz,Y., 1990, An approach to the origin of young volcanic rocks of Western Turkey: In: Tectonic Evolution of the Tethyan Region. Ed: A. M. C. Şengör, Nato ASI Series Vol: 259 Klower Academic Publishers Boston/London, 137-159.